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What Is Marine Habitat Mapping and Why Do Managers Need It?

Jon Kurland
NOAA, National Marine Fisheries Service, Juneau, Alaska

Doug Woodby
Alaska Department of Fish and Game,
Division of Commercial Fisheries, Juneau, Alaska

Abstract

The waters off Alaska's coast support abundant and nationally significant populations of fish and marine mammals, yet resource managers lack basic information about the marine habitats that sustain this bounty. Fishermen and geologists can tell us broadly about the types of seafloor found in various areas, but such information tends to be patchy at best and the seafloor can vary dramatically over a small area. To make informed decisions about human activities that affect the oceans, managers need fairly high resolution maps of the physical and biological features that constitute habitat for fish, crabs, whales, sea lions, and other marine life. Habitat maps are important not only for fishery managers, but also for decision makers regarding oil and gas development, marine mining, and other activities that can affect habitats for marine life. Marine habitat mapping can be defined as the collection and synthesis of physical and biological data necessary to differentiate environmental features that are meaningful to marine organisms—the features that make a particular area suitable or preferable for basic life functions such as feeding, reproduction, and avoiding predators. Habitat maps coupled with biological surveys help scientists learn which environments contribute most to the growth, reproduction, and survival of marine species. Managers can use such habitat maps to design protective measures for necessary habitats with greater certainty about societal benefits. In short, habitat mapping is a key element for improving the sustainable management of Alaska's living marine resources. This paper highlights several examples of marine habitat mapping and their value to management decisions.

Introduction

What is marine habitat mapping? Biologists, geologists, cartographers, resource managers, and others may answer that question differently depending upon their particular perspective. As one considers the various technologies available for mapping the marine environment, it is helpful to start from a common understanding of what we mean by habitat mapping, and also to appreciate why habitat maps are needed by managers who are called upon to make decisions about the use of marine resources.

The waters off Alaska's coast support abundant and nationally significant populations of fish and marine mammals. Alaska waters provide about half of all seafood caught in the United States. The seafood industry is the largest private sector employer in Alaska, and subsistence fisheries and marine mammal harvests are very important for Alaskans. Alaska also has significant ocean-dependent coastal communities, and Alaska fishing ports consistently rank among the top in the United States in landings and value (Witherell 2004). Unfortunately, resource managers lack basic information about the marine habitats that sustain this bounty. Fishermen and geologists can tell us broadly about the types of seafloor found in various areas—mud, sand, rocky pinnacles, scattered gravel, etc.—but such information tends to be patchy at best, and just like terrestrial environments, the seafloor can vary dramatically over a small area. To make informed decisions about human activities that affect the oceans, managers need fairly high resolution maps of the physical and biological features that constitute habitat for fish, crabs, whales, sea lions, and other marine life. But again, what do we mean by habitat mapping?

Marine habitat maps can take a variety of forms and can emphasize different things. Some examples from around the world serve to illustrate the commonalities and differences between various types of habitat maps. Fig. 1 is a map of the Midway Islands in Hawaii, showing in different colors a variety of nominal habitat types: sand, hard bottom with coral, hard bottom without coral, deep water, reef crest, etc. Fig. 2 is a map of marine habitats in the Northern Natural Resource Management Region of Tasmania, and uses a similar approach to show types of reef, seagrasses, hard sand, and so forth. Fig. 3 from Abaco in the Bahamas also uses colors to differentiate habitat types, and combines that with photographs that are intended to be representative of each different habitat zone: dense seagrass, sparse seagrass, patch reef, mangrove, and the like. Fig. 4 is a map of Essential Fish Habitat (identified under the Magnuson-Stevens Fishery Conservation and Management Act) for Pacific ocean perch in the Gulf of Alaska. Instead of mapping habitat types or features, it shows the general distribution of the species, with the areas most commonly used by juveniles and adults being considered their essential habitat. Fig. 5 focuses on geology

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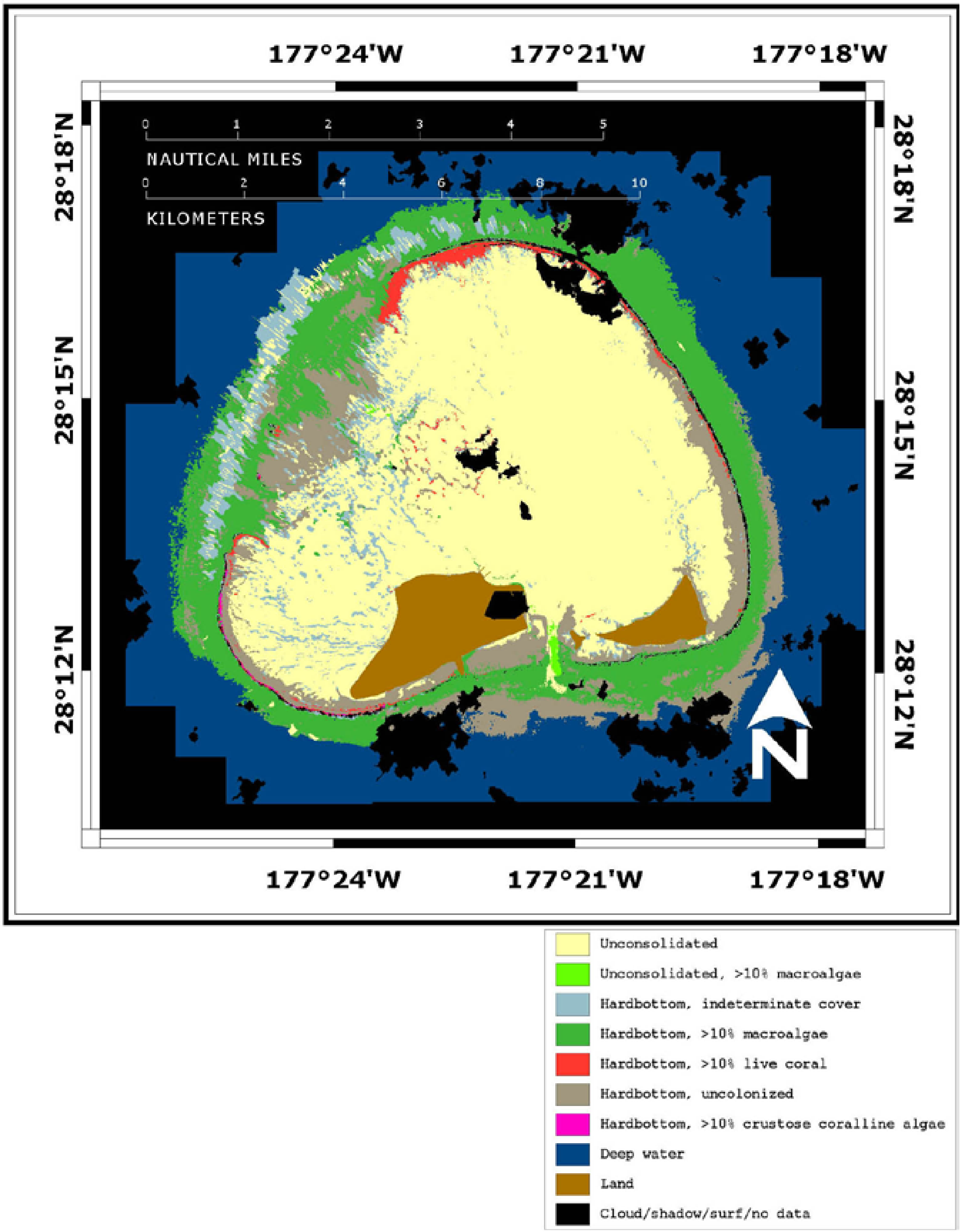

Figure 1. **Example of marine habitat mapping from the Midway Islands, Hawaii. Source: http://ccma.nos.noaa.gov/ecosystems/coralreef/nwhi/welcome.html.**

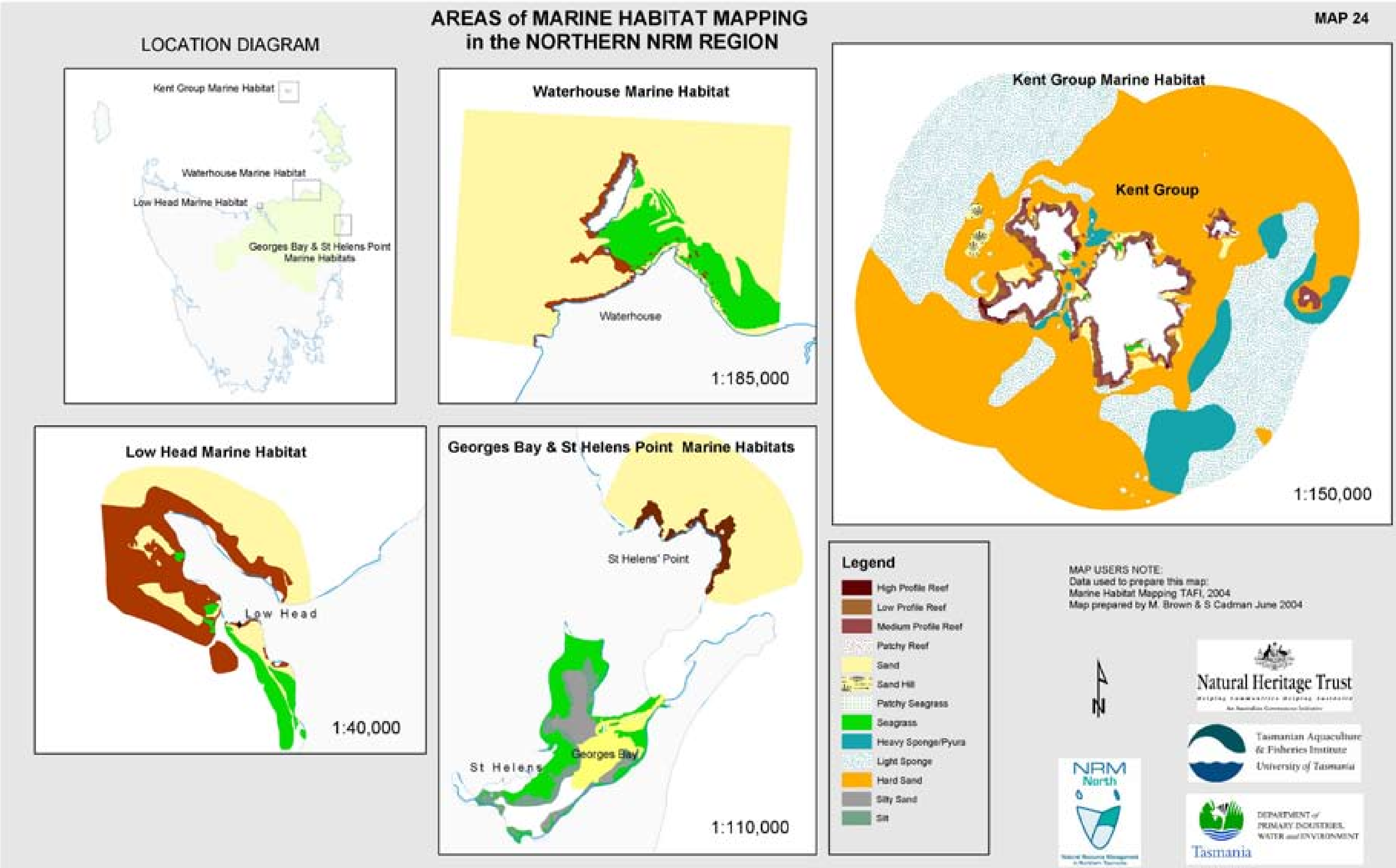

Figure 2. Example of marine habitat mapping from the Northern Natural Resource Management Region of Tasmania. Source: http://www.nrmtas.org/library/north/images/24-marinehabitatmapping.jpg.

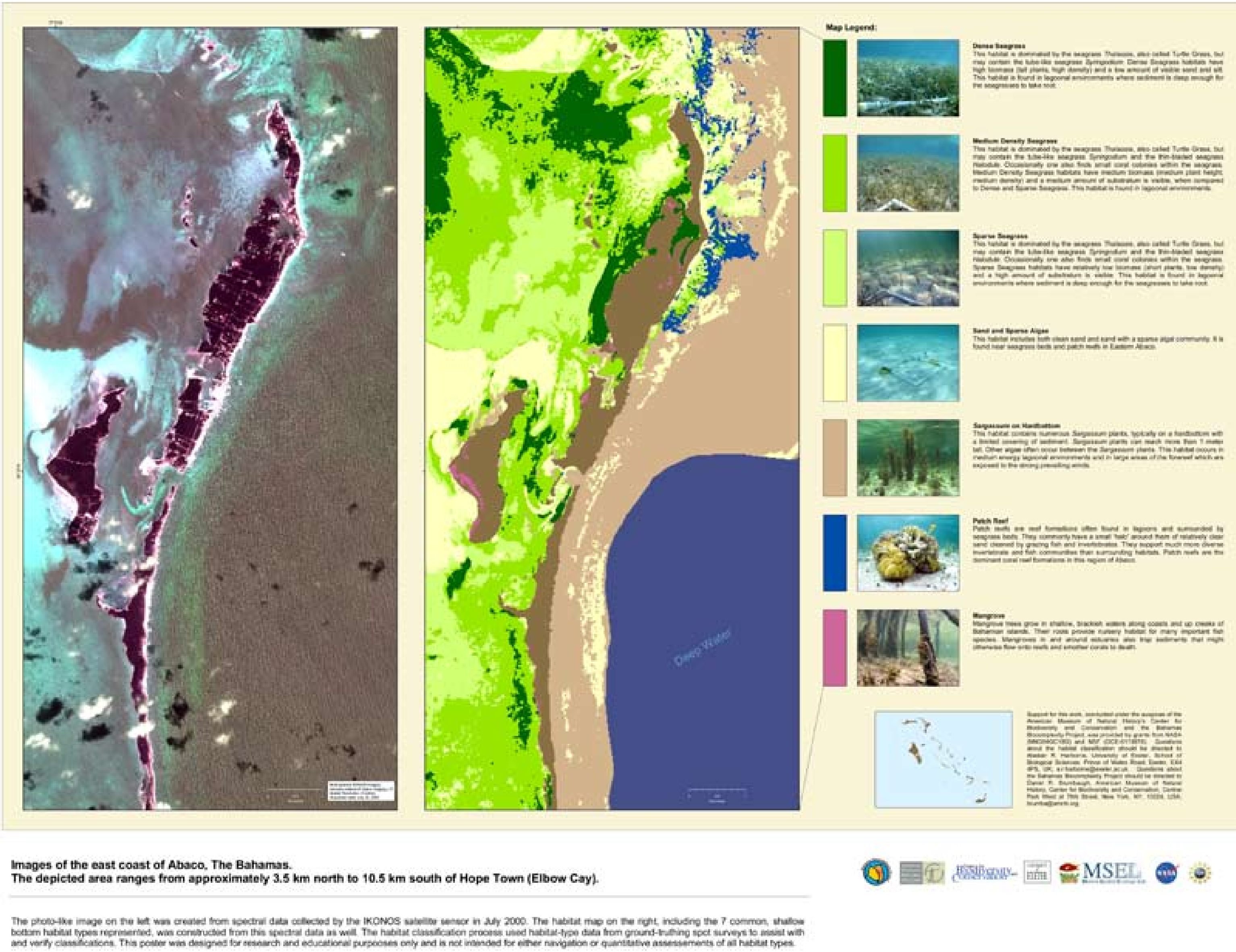

Figure 3. Example of marine habitat mapping from Abaco in the Bahamas. Source: http://bbp.amnh.org/website/HabitatMaps/AbacoHabitatBBPHighRez.pdf

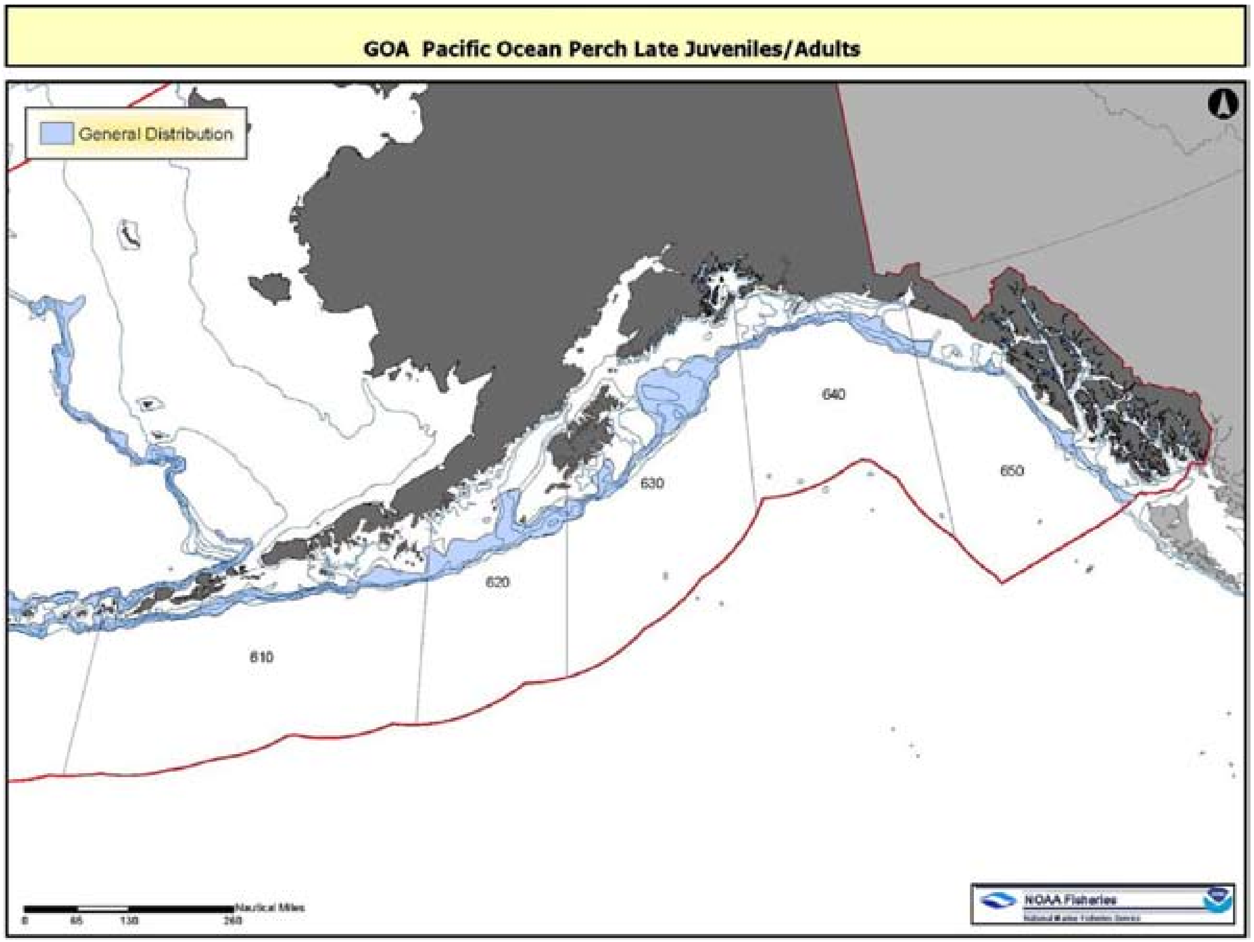

Figure 4. Example map of Essential Fish Habitat identified under the Magnuson-Stevens Fishery Conservation and Management Act for Pacific ocean perch in the Gulf of Alaska. Source: http://www.fakr.noaa.gov/npfmc/fmp.htm

rather than biological features, showing different types of substrate off the coast of New Hampshire. Finally, Fig. 6 shows the complexity of overlaying, on a single map, different densities of various important marine animals and plants found off British Columbia. Each of these six maps shows marine habitats, differentiating certain areas based on specific criteria that serve a particular purpose.

Conceptually, it may be helpful to think of habitat mapping as a spatial aggregation of different types of information ranging from fairly stable characteristics of a marine area to highly variable features that change with the seasons or other physical or biological influences. Pertinent elements of habitat maps may include bathymetry, geological substrate, marine vegetation, attached epifauna, and features that can be quite ephemeral such as temperature, currents, and prey availability. To account for natural variability it is best to use time series of data, particularly for the more ephemeral habitat features. To boil this down, we suggest the following working definition. Marine habitat mapping can be defined as the collection and synthesis of physical and biological data necessary to differentiate environmental features that are meaningful to marine organisms—the features that make a particular area suitable or preferable for basic life functions such as feeding, reproduction, and avoiding predators. (In this context "marine organisms" could include seabirds in addition to marine life such as fish, crabs, and marine mammals, although the discussion in this paper will not extend to terrestrial habitats used by seabirds for nesting etc.)

Why managers need marine habitat maps

Put simply, managers need marine habitat maps to help them make informed decisions about human activities that affect the oceans. Good quality habitat maps are extremely valuable for fishery managers, who decide where and when fish can be caught as well as the allowable gears and quantities of catch, because maps can help identify sensitive habitat areas that may warrant protection (Hogarth 2005). When habitat maps are coupled with biological surveys, they can help managers understand which environments contribute most to the growth, reproduction, and survival of marine species. Likewise, habitat maps are important for decision makers regarding oil and gas development, marine mining, and other

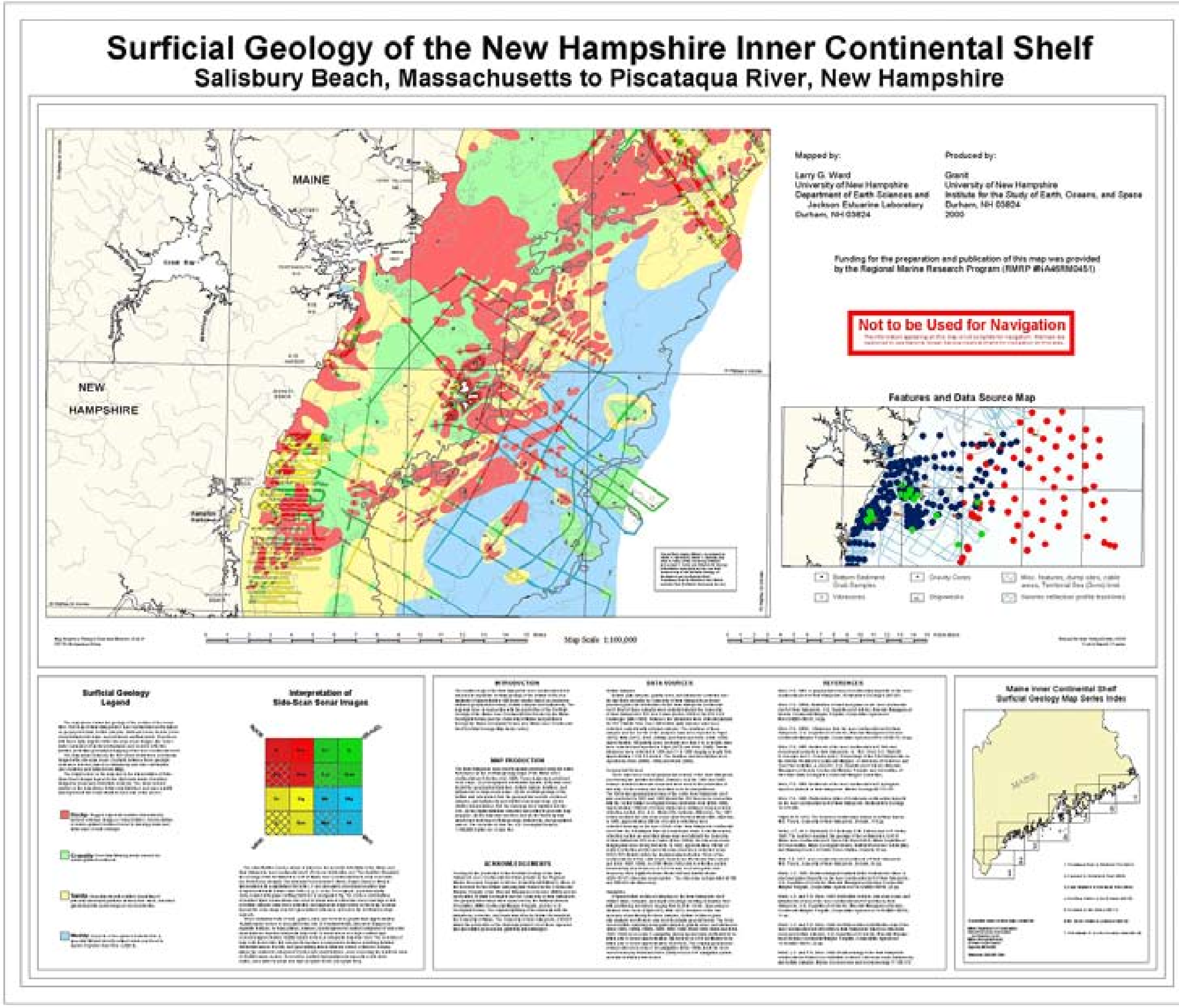

Figure 5. Example of marine substrate mapping from New Hampshire. Source: http://www.marine.unh.edu/jel/coastal_geology/maps.htm.

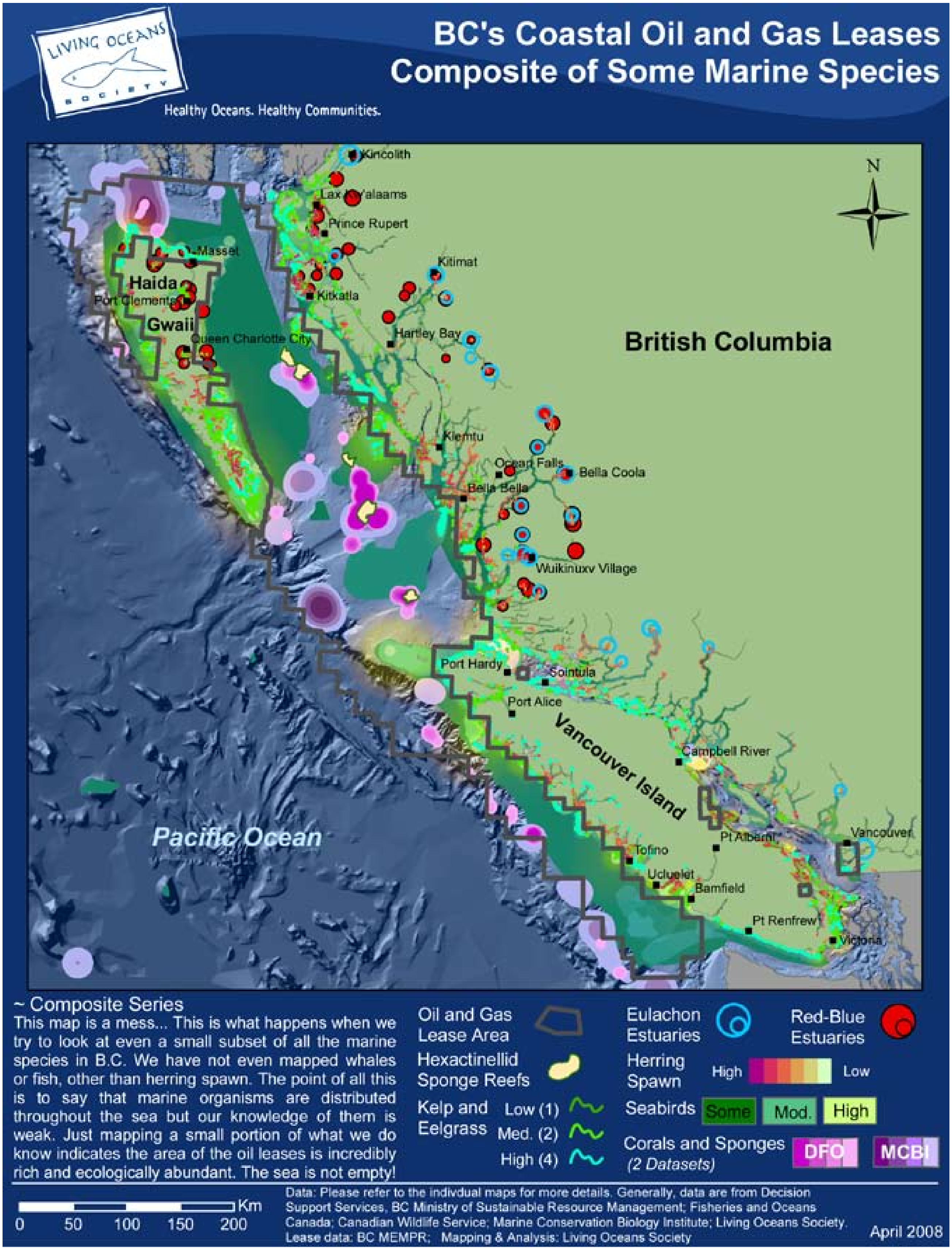

Figure 6. Example of marine habitat mapping from British Columbia. Comments in lower box were authored by Living Oceans Society. Source: Living Oceans Society.

activities that can affect habitats for marine life. Marine habitat maps enable managers to design protective measures for necessary habitats with greater certainty about the resulting societal benefits. In short, habitat maps can improve the sustainable management of living marine resources.

For fishery managers in particular, reliable habitat maps are sorely needed. Healthy and productive marine habitats are the foundation for sustainable fisheries and vibrant marine ecosystems. Under the Magnuson-Stevens Fishery Conservation and Management Act, federal fishery managers must identify and describe essential fish habitat, minimize to the extent practicable the adverse effects of fishing on such habitat, and identify other actions to promote the conservation and enhancement of such habitat. Federal agencies that authorize, fund, or undertake actions that may adversely affect essential fish habitat must consult with the National Marine Fisheries Service (NMFS), and NMFS must provide conservation recommendations to minimize adverse effects (NMFS 2002, U.S. Congress 2006). Regional fishery management councils are also encouraged by federal regulation to identify and protect habitat areas of particular concern (NMFS 2002). Likewise, under Alaska state law the Alaska Board of Fisheries may close waters to fishing for the protection of habitat (AS 16.05.251[a][7]) and may recommend to the Alaska State Legislature areas to be set aside for habitat protection with restriction on other activities as well (AS 16.05.251[a][1]).

In Alaska, many species of groundfish and shellfish exhibit a strong dependence on benthic habitat. In recognition of the importance of healthy habitats for sustainable fishery management, the North Pacific Fishery Management Council (NPFMC) has adopted an extensive suite of habitat protection measures for council-managed fisheries (Fig. 7). However, in most of these cases NPFMC and NMFS did not have very detailed information about the habitat features within these management areas. Managers acted based on the best available scientific information, but with improved habitat mapping it may be possible to refine some of these management measures to improve the focus on habitat features that are most vulnerable to disturbance by fishing gear that contacts the bottom, and allow fishing to resume in less sensitive areas. Likewise the Alaska Board of Fisheries has adopted gear restrictions for state managed fisheries in some areas to protect habitat, yet those measures could probably be refined with improved habitat mapping.

In some cases fishery managers can use marine habitat mapping to undertake habitat-based stock assessments, where a population is estimated based on the abundance of an organism in a particular type of habitat multiplied by the available area of such habitat. Currently this is possible only for a few species because of data limitations. For example, density estimates of yelloweye rockfish in the eastern Gulf of Alaska have been made from a submersible across a variety of benthic habitats, with areas of rocky habitat determined in part from seafloor substrate maps produced with sidescan and multibeam echosounder data, and in part from records of commercial harvest locations (O'Connell and Carlile 1993, Brylinsky et al. 2007).

In other cases a lack of habitat-specific density information is a significant limitation to management. For example, for various other Alaska rockfish, such as Pacific ocean perch, abundance is estimated with trawls except in rocky areas that are considered untrawlable, for which density estimates are generally not available (Hanselman et al. 2007). For these rockfish and others (northern rockfish and other slope rockfish) abundance estimates are likely to be biased without habitat specific density data, especially where densities are likely to be higher in preferred rocky habitat. A similar concern applies to managed crab species, including red king crab in Southeast Alaska, where surveys are stratified based on prior survey densities but without the advantage of information on the spatial distribution of benthic habitats that are important to crab (Clark et al. 2002). Over time, improved habitat mapping coupled with knowledge of habitat requirements or preferences of managed species may lead fishery managers to better estimate how much production of a given species can be expected per unit of habitat.

Examples

Several examples from Alaska illustrate the importance of habitat maps in facilitating informed resource management decisions: Aleutian Islands coral gardens, the Sitka Pinnacles Marine Reserve, eastern Gulf of Alaska corals, and a nearshore example—the South Lena subdivision in Juneau. In most of these examples, exploratory dive surveys (either by scuba or submersible) discovered unusual marine habitat features that prompted resource managers to take action. While opportunistic uses of habitat mapping data can be beneficial, having a more systematic collection of detailed marine habitat maps would enable managers to assess the rarity of habitat features and the ecological context surrounding particular habitats, facilitating better informed and less reactive decision making.

Aleutian Islands coral gardens

Exploration of the central Aleutian Islands in 2002 with a manned submersible led to the discovery of unusual "coral garden" habitats—areas with very high densities and diversity of cold water corals and sponges (Heifetz et al. 2005). Following the initial discovery of the coral gardens by NMFS scientists, surveys were conducted cooperatively by NMFS, the University of Alaska, and the Alaska Department of Fish and Game to map the bathymetry and the benthic habitats across a systematic sample of the ocean floor in the central Aleutian Islands to better understand the distribution and abundance of corals and sponges in the area.

The discovery of the coral gardens and the accompanying still images and videos received widespread attention, eventually leading the North Pacific Fishery Management Council to vote to close six areas to all bottom-tending fishing gear and anchoring by fishing vessels (Fig. 8). The coral

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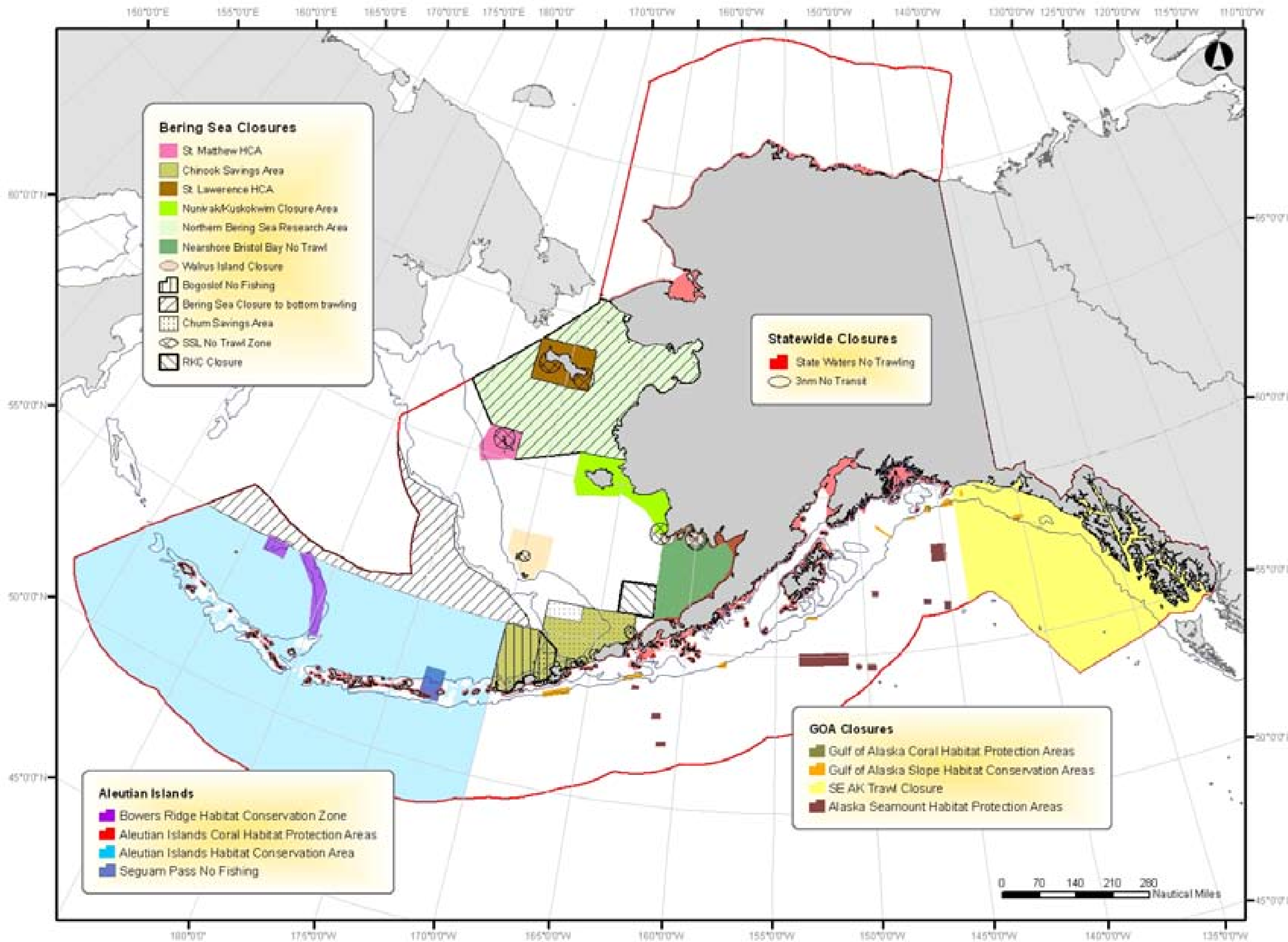

Figure 7. **Habitat protection measures adopted by the North Pacific Fishery Management Council.**

garden areas are known in federal regulations as the Aleutian Islands Coral Habitat Protection Areas. They encompass a total of 110 nm² and the closures took effect in 2006.

Sitka Pinnacles Marine Reserve

The Sitka Pinnacles Marine Reserve was established in 1999 to prohibit all bottom fishing and anchoring in a 9 nm² area surrounding two rocky submarine pinnacles southwest of Cape Edgecumbe near Sitka (see Fig. 9). Surveys conducted by the Alaska Department of Fish and Game documented the high relief bottom habitats with dense concentrations of lingcod and rockfish (O'Connell et al. 1998; see Fig. 10). That information, and a perception that increased fishing effort could damage the habitat and lead to depletion of the lingcod stock, prompted closure of the area following an extensive public process by the Alaska Board of Fisheries and the North Pacific Fishery Management Council.

Eastern Gulf of Alaska corals

The Gulf of Alaska Coral Habitat Protection Areas are five small areas off the outer coast of Southeast Alaska—four located on the Fairweather Grounds and one located off Cape Ommaney (Fig. 11). Surveys conducted by the NMFS Alaska Fisheries Science Center with a manned submersible documented unusually dense thickets of red tree corals (*Primnoa* spp.) at these sites (Heifetz 2002). The North Pacific Fishery Management Council voted to close these areas, totaling 13.5 nm², to all bottom tending fishing gear and anchoring by fishing vessels. The closures took effect in 2006. The sizes and shapes of the closure areas were negotiated with representatives of the longline fishing industry to allow fishermen continued access along productive depth contours near the coral areas. The site-specific habitat mapping combined with videos and still photographs of the corals provided the impetus for the closures.

South Lena subdivision in Juneau

The South Lena residential subdivision in Juneau provides a different kind of example of the utility of habitat mapping. NMFS scuba divers investigated the site of a proposed sewage outfall from a new housing development and discovered an uncommon grove of sea pens (a soft coral) off Lena Beach (Fig. 12). The nearshore subtidal habitat in that area had not been mapped, so local government officials were unaware of any sensitive resources that could be affected by the proposed sewage discharge. Based on the NMFS dive report and recommendations, the City and Borough of Juneau changed course and required on-site septic systems rather than a sewage outfall pipe.

Conclusions

Marine habitat mapping is a simple concept, but to maximize the effectiveness of habitat maps it helps to develop a common understanding of the kinds of data that can be collected with various technologies and the types of information managers find most useful for decision making. Maps of marine substrate, vegetation, fish abundance, or other parameters can be informative on their own, and integrating or layering such data can be even more useful. Still, good habitat maps should include more than aggregations of physical and biological data; ideally they should be accompanied by information that provides enough ecological context for managers to be able to distinguish habitat features that are of relatively more or less value to target species of fish or other marine life.

Why should we care about marine habitat mapping? First, habitat maps can integrate physical and biological data spatially to suggest which environmental features may matter most for particular marine species. Second, habitat maps can facilitate informed decisions by helping managers take off the metaphorical blindfold and see differences in habitat characteristics. Third, habitat maps can encourage decision making based on ecosystem relationships, rather than the needs of a single species. Fourth, habitat maps can help move fishery managers toward habitat-based stock assessments, whereby scientists can calculate how much fish production to expect per unit of habitat. In summary, habitat maps can add information that is not currently used in decision making, hopefully improving sustainable management of valuable living marine resources.

An important caveat, of course, is that habitat mapping alone will not magically transform fishery management and enable managers to make ecosystem-based decisions. The examples of habitat mapping presented in this paper illustrate how spatial information about habitat features can help support resource management decisions, but knowing where these interesting habitat features are located only solves part of the problem. For species with strong benthic habitat affinities it is equally important to be able to identify the relative importance of available habitats and their contribution to species productivity. While this has been accomplished to some extent for yelloweye rockfish in the eastern Gulf of Alaska, the task remains largely undone for most of the other managed stocks in the North Pacific region. Gathering such information is a significant challenge that will require many years of focused work. Given the often substantial costs of seafloor habitat mapping, we expect that improved habitat mapping combined with a better understanding of habitat requirements for certain marine organisms will progress at only a modest pace, but that the efforts will enable managers to make better informed decisions regarding human activities that affect marine resources.

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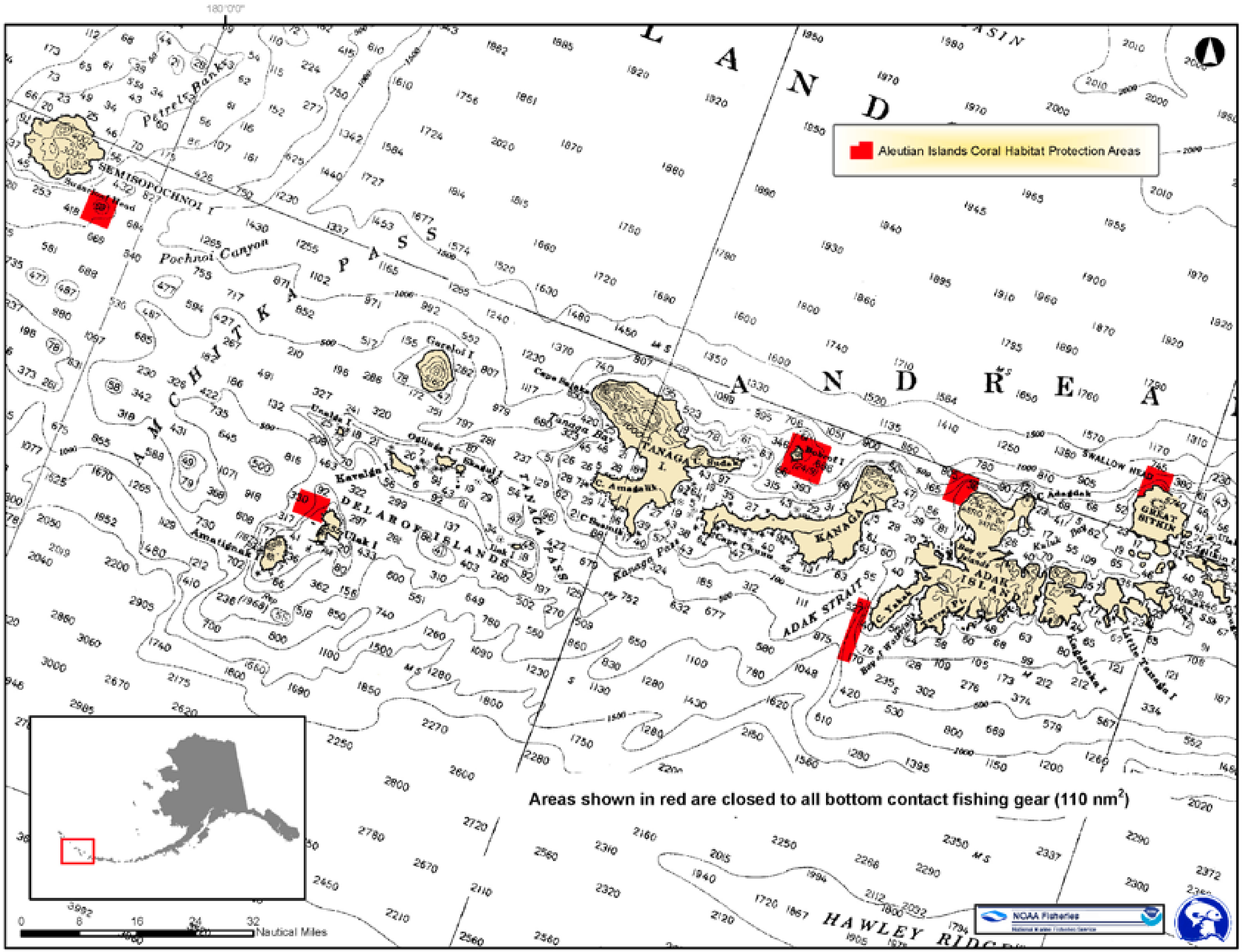

Figure 8. The Aleutian Islands Coral Habitat Protection Areas.

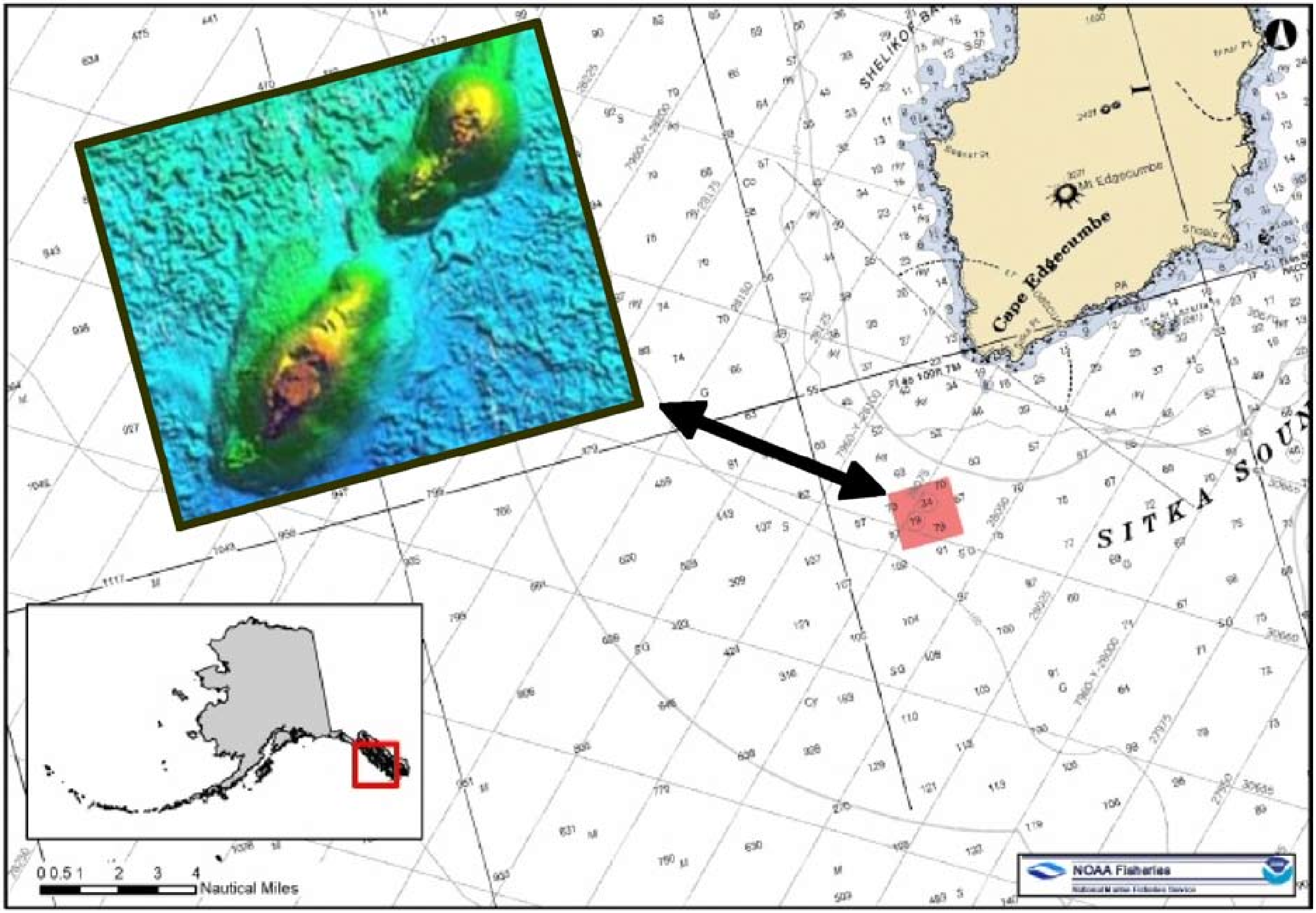

Figure 9. **Sitka Pinnacles Marine Reserve. The inset image (source: ADFG) shows a multibeam bathymetric map of volcanic cones on the seafloor, surrounded by lava flows. Deep areas are blue, shallow areas are orange. The image has artificial illumination from the northeast.**

Figure 10. Lingcod at Sitka Pinnacles. Photo credit: Alaska Department of Fish and Game groundfish project.

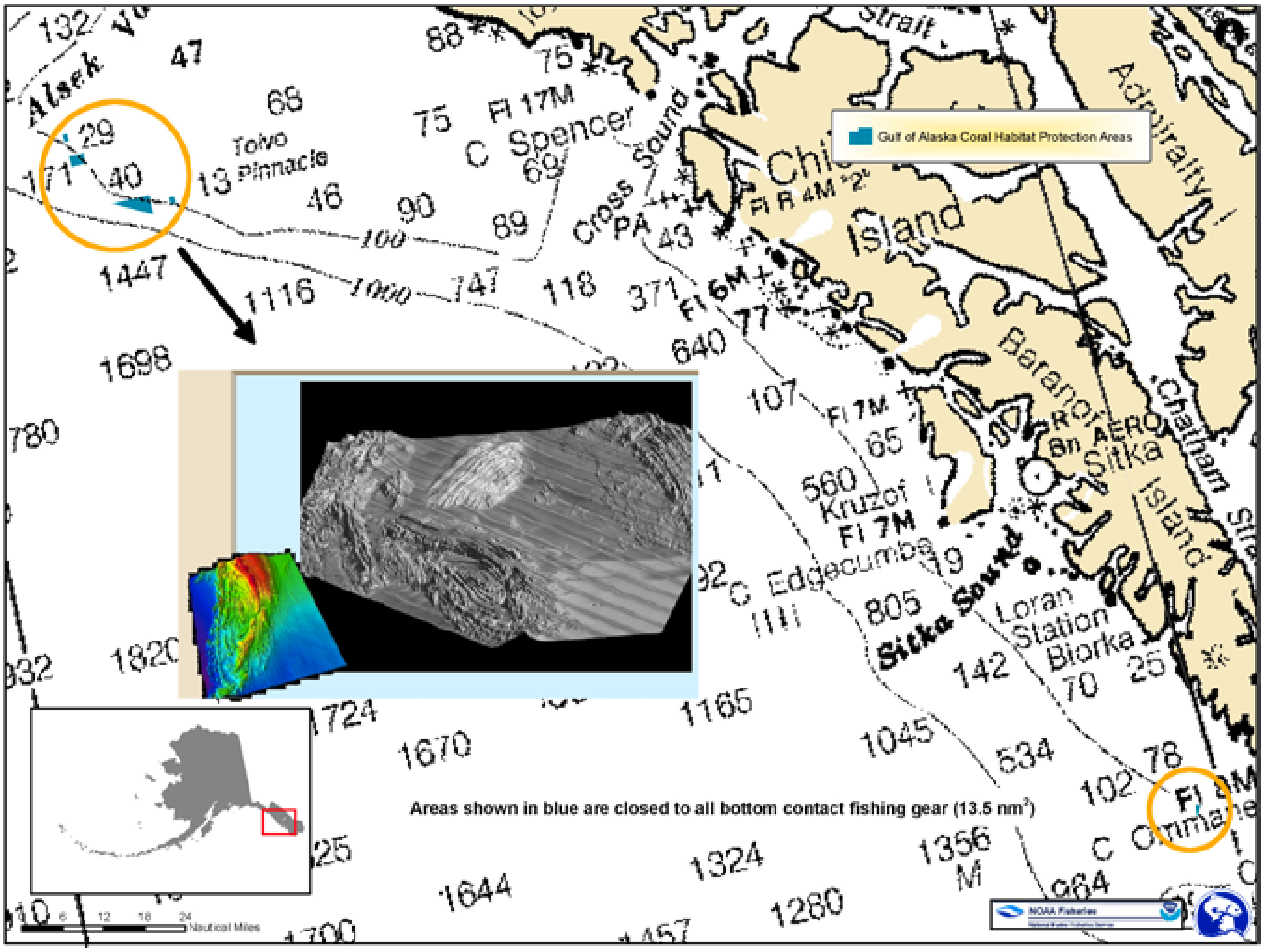

Figure 11. **Gulf of Alaska Coral Habitat Protection Areas near Sitka, Alaska. The yellow circles on the main image indicate coral habitat protection areas near Cape Ommaney and on the Fairweather Grounds. The inset maps from the Fairweather Grounds were produced from multi-beam sonar data (source: ADFG), and show highly structured bedrock outcrops surrounded by unconsolidated sediment. The grayscale image shows backscatter draped over a digital terrain model of seafloor bathymetry, with artificial illumination from the right. Grayscale values in the image indicate a combination of backscatter intensity (high intensity is bright) and light/shadow from the artificial illumination. The color image shows seafloor bathymetry of a bedrock outcrop, with deep areas in blue and shallow areas in red.**

Figure 12. Sea pens (soft corals) off Lena Beach in Juneau. Photo by Sue Walker.

References

Brylinsky, C., D. Carlile, and J. Stahl. 2007. Assessment of the demersal shelf rockfish stock for 2007 in the Southeast Outside District of the Gulf of Alaska. In: Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, Alaska, pp. 843-888.

Clark, J.E., S. Hinkley, and T. Koeneman. 2002. Restratification of red king crab stock assessment areas in Southeast Alaska. In: A.J. Paul, E.G. Dawe, R. Elner, G.S. Jamieson, G.H. Kruse, R.S. Otto, B. Sainte-Marie, T.C. Shirley, and D. Woodby (eds.), Crabs in cold water regions: Biology, management, and economics. Alaska Sea Grant College Program, University of Alaska Fairbanks, pp. 457-473.

Hanselman, D., J. Heifetz, J.T. Fujioka, S.K. Shotwell, and J.N. Ianelli. 2007. Gulf of Alaska Pacific ocean perch. In: Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, Alaska, pp. 563-622.

Heifetz, J. 2002. Coral in Alaska: Distribution, abundance, and species associations. Hydrobiologia 471:19-28.

Heifetz, J., B.L. Wing, R.P. Stone, P.W. Malecha, and D.L. Courtney. 2005. Corals of the Aleutian Islands. Fish. Oceanogr. 14:131-138.

Hogarth, W.T. 2005. Keeping our fisheries sustainable. In: P.W. Barnes and J.P. Thomas (eds.), Benthic habitats and the effects of fishing. Am. Fish. Soc. Symp. 41:11-17.

NMFS. 2002. Final rule implementing the Magnuson-Stevens Act Essential Fish Habitat provisions. National Marine Fisheries Service, 67 Federal Register 2343, 1/17/02 (codified at 50 CFR Part 600, subparts J and K).

O'Connell, V.M., and D. Carlile. 1993. Habitat-specific density of yelloweye rockfish *Sebastes ruberrimus* in the eastern Gulf of Alaska. Fish. Bull. U.S. 91:304-309.

O'Connell, V.M., W.W. Wakefield, and H.G. Greene. 1998. The use of a no-take marine reserve in the eastern Gulf of Alaska to protect essential fish habitat. In: M.M. Yoklavich (ed.), Marine harvest refugia for West Coast rockfish: A workshop. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-255, pp. 125-132.

U.S. Congress. 2006. Magnuson-Stevens Fishery Conservation and Management Act. Public Law 94-265, as amended, 16 U.S.C. 1853, 1855.

Witherell, D., ed. 2004. Managing our nation's fisheries: Past, present and future. Proceedings of a conference on fisheries management in the United States held in Washington, D.C., November 2003, pp. 133-134.

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